



Description of new species of algal-boring *Limnoria* (Crustacea, Isopoda, Limnoriidae) from Japan and redescription of *Limnoria segnoides* Menzies, 1957 and *L. nagatai* Nunomura, 2012

HIROKI YOSHINO¹ & TAKESHI A. OHSAWA²

¹Graduate School of Agricultural and Life Sciences, University of Tokyo, Tokyo, Japan. E-mail: yosino@fr.a.u-tokyo.ac.jp

²Department of Biology, Graduate School of Science, Chiba University, Chiba, Japan

Abstract

Previous research on the mitochondrial COI gene sequences of several populations of *Limnoria nagatai* Nunomura suggested a cryptic species from the Sea of Japan. A new species of algal-boring limnoriid is here described. *Limnoria furca* sp. nov. was collected from the holdfasts of *Eisenia bicyclis* on the Oki Islands and the Sea of Japan coast of Honshu and Kyushu Islands, Japan. *L. furca* sp. nov. is diagnosed morphologically by lacking a mandibular palp, faint subparallel carinae on the pleotelson, faint Y-shaped carinae on pereonite 5, the bifid lacinia mobilis of right mandible and the shapes of the secondary unguis on the pereopods. Similar species, *L. segnoides* Menzies, 1957 and *L. nagatai* Nunomura, 2012, are redescribed on the basis of the holotypes.

Key words: *Eisenia bicyclis*, Japan, *Limnoria furca* sp. nov., *Limnoria nagatai*, *Limnoria segnoides*, Sea of Japan

Introduction

The family Limnoriidae (Crustacea, Isopoda, Limnoriidea) is composed of three genera, *Paralimnoria* Menzies, 1957, *Limnoria* Leach, 1814, and *Lynseia* Poore, 1987. Eleven species in two genera, *Paralimnoria* and *Limnoria*, are found from Japanese coasts: *P. andrewsi* (Calman, 1910); *L. borealis* Kussakin, 1963; *L. hiradoensis* Nunomura 2008; *L. japonica* Richardson 1909; *L. lignorum* (Rathke, 1799); *L. nagatai* Nunomura 2012; *L. rhombipunctata* Yoshino, Watabe & Ohsawa, 2017; *L. saseboensis* Menzies, 1957; *L. segnoides* Menzies, 1957; *L. tuberculata* Sowinsky, 1884; *L. zinovae* Kussakin, 1963 (Richardson 1909, Shiino 1950, Menzies 1957, Kussakin 1963, Nunomura 2008, Nunomura 2012, Yoshino *et al.* 2017). Within these species, *L. nagatai*, *L. rhombipunctata*, *L. segnoides* and *L. zinovae* are seagrass or algal borers (Menzies 1957, Kussakin 1963, Yoshino *et al.* 2017, Yoshino *et al.* 2018). *L. rhombipunctata* and *L. zinovae* have been collected from the rhizomes of the seagrass *Phyllospadix iwatensis* in Japan, but *L. rhombipunctata* in South Korea was found from the rhizomes of the seagrass *Zostera* sp. (Song *et al.* 2017). *L. segnoides* was reported from Misaki, Kanagawa Prefecture in low tide level in Japan, by washing the red alga *Corallina*.

Yoshino *et al.* (2018) suggested that *L. nagatai* bored into the holdfasts of the macroalgae *Eisenia bicyclis* (Kjellman) Setchell, 1905 and *E. arborea* Areschoug, 1876 along the Pacific coasts of Honshu and Shikoku Islands, but the individuals in *E. bicyclis* along the Sea of Japan coasts of Honshu, Kyushu and Oki Islands had approximately 15% genetic divergence in mitochondrial cytochrome c oxidase subunit I (COI) gene, suggesting a cryptic species. More detailed examination showed these specimens belonged to a new species, *L. furca* sp. nov.

L. furca sp. nov. is most similar to *L. segnoides* and *L. nagatai*. The description papers for *L. segnoides* and *L. nagatai* did not provide sufficient information to distinguish these 3 species. Therefore, the present contribution re-examines *L. segnoides*, which is deposited at Zoologisk Museum, Københavns Universitet (ZMUC), and *L. nagatai*, Toyama Science Museum (TOYA) and Kitakyushu Museum of Natural History (KMNH), in an effort to clarify their differences. Some body parts of type specimens of *L. segnoides* and *L. nagatai* were redrawn.

Specimens we collected are deposited with the Kitakyushu Museum of Natural History & Human History (KMNH), Fukuoka Prefecture, Japan.

Materials and methods

Macroalgae, *Eisenia bicyclis*, growing on the sea bed in subtidal zone were collected by using a knife and scissors, from Minamisanriku-cho and Ishinomaki-shi in Miyagi Prefecture, Hitachinaka-shi and Hitachi-shi in Ibaraki Prefecture, Kamogawa-shi, Choshi-shi, Futtsu-shi and Tateyama-shi in Chiba Prefecture, Shimoda-shi in Shizuoka Prefecture, Oki Islands in Shimane Prefecture, Munakata-shi in Fukuoka Prefecture, and Karatsu-shi in Saga Prefecture. The algae samples were taken immediately to the laboratory and identified by morphology.

The individuals of *Limnoria* in the holdfasts were picked out with tweezers and fixed in 100% ethanol. After DNA extraction following Yoshino *et al.* (2018), we stored the specimens in 70% ethanol. Drawings were prepared with light microscope. Some samples were observed under SEM.

We observed the type specimens of *Limnoria segnoides* and *L. nagatai* under light microscopes and SEM. The holotype of *L. segnoides* from ZMUC was not dissected, while some specimens of *L. nagatai* from TOYA were dissected.

Taxonomy

Limnoriidea Poore, 2002

Limnoriidae White, 1850

Genus *Limnoria* Leach, 1814

Limnoria furca, sp. nov.

Figs. 1–4

Material examined. *Holotype*: male 2.4 mm, Oki Islands, Shimane Prefecture, Japan, 36°06'33" N, 133°07'50" E, subtidal zone, *Eisenia bicyclis* holdfasts, Takeshi A. Ohsawa and Hiroki Yoshino, 14 March 2014 (KMNH IvR 500953).

Paratypes: male 2.2 mm, Oki Islands, Shimane Prefecture, Japan, 36°06'33" N, 133°07'50" E, subtidal zone, *Eisenia bicyclis* holdfasts, Takeshi A. Ohsawa and Hiroki Yoshino, 14 March 2014 (KMNH IvR 500953); non-ovigerous females, 2.1–3.2 mm (KMNH IvR 500954), same as KMNH IvR 500953; non-ovigerous female, 3.1 mm, Munakata-shi, Fukuoka prefecture, Japan, 33°53'22" N, 130°31'29" E, subtidal zone, *Eisenia bicyclis* holdfasts, Takeshi A. Ohsawa A. Takeshi and Hiroki Yoshino, 4 March 2014 (KMNH IvR 500950); males, 2.5–2.6 mm, Karatsu-shi in Saga prefecture, Japan, 33°33'24" N, 129°50'46" E, subtidal zone, *Eisenia bicyclis* holdfasts, Takeshi A. Ohsawa A. Takeshi and Hiroki Yoshino, 22 June 2013 (KMNH IvR 500951); females, 2.5–3.1 mm (KMNH IvR 500952), same as KMNH IvR 500951.

Type locality. Oki Island, Shimane prefecture, Japan.

Description. *Body* oblong and pale yellow in 70% ethanol. *Head* almost globular. *Eyes* black in color, each with 7–8 ommatidia. Most of dorsal surface of pereonite, pleon and pleotelson covered with small pores. *Pleonite* composed of 5 distinct segments. *Pereonal* segment 1 longest, approximately 1.5 times longer than segment 2. Segments 2–4 subequal length. Posterior pereonal segments 4–7 progressively shorten. Coxal plates of pereonal segments 2–4 rectangular in shape and those of posterior segments prolonged acutely at posterior angle. Pereonites 6, 7 and pleonites 1–4 each with transverse row of many small setae.

Pleonite 5 0.5–0.6 times as long as pleotelson (Fig. 1, 2A). Pleonite 5 medially with 1 strong tubercle and 1 weaker tubercle posteriorly (Fig. 1), sometimes imperceptible (Fig. 2A). Pleonite 5 dorsomedially with often ill-defined Y-shaped carinae on which few scale spikes form line. These spikes continuing laterally and pleonite 5 fringed with spikes.

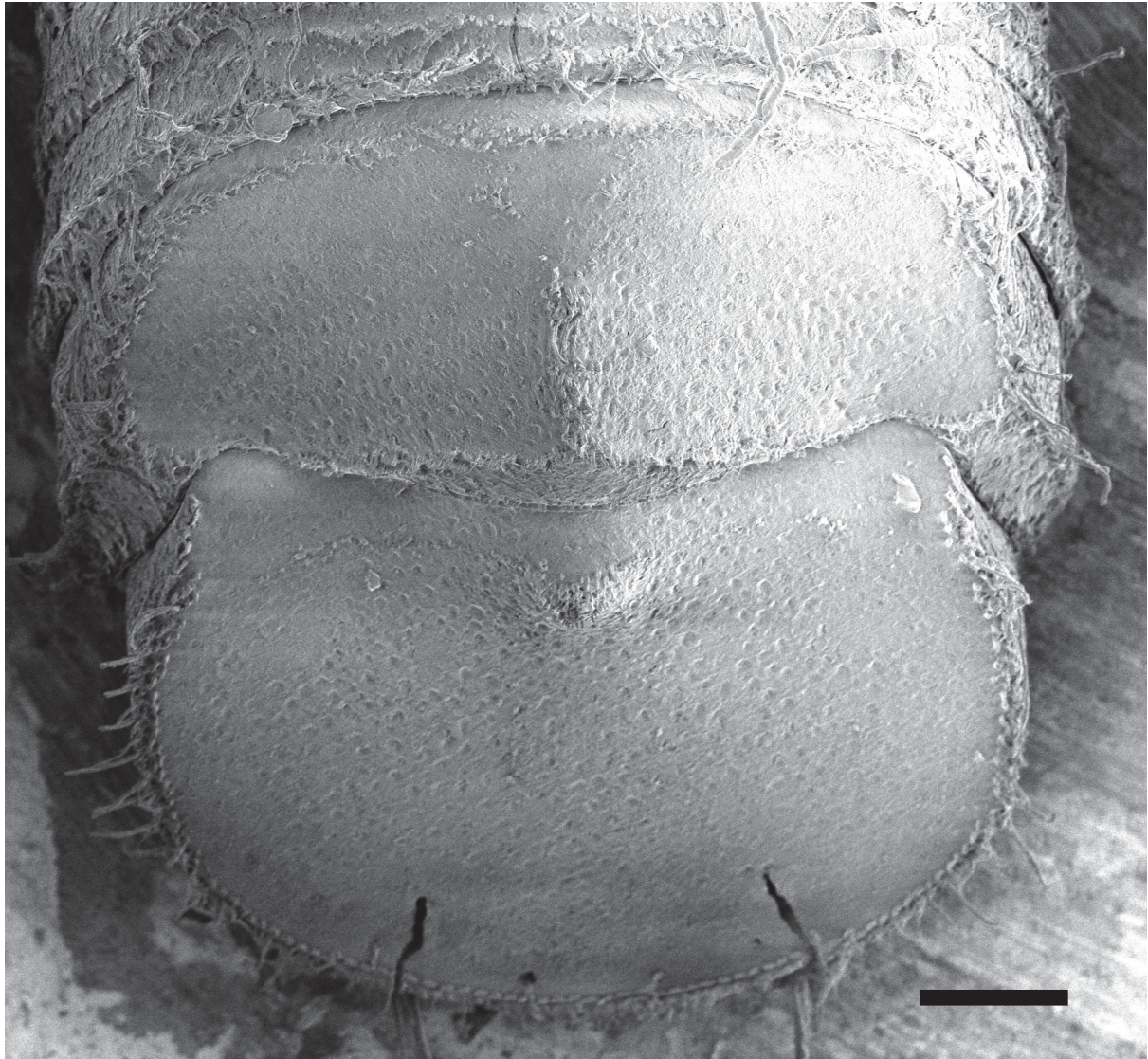


FIGURE 1. *Limnoria furca* sp. nov. Male KMNH IvR 500951. Dorsal view of pleonite 5, pleotelson. Scale bars: 0.1 mm.

Pleotelson 0.6–0.9 times as long as wide, medially with 1 large median tubercle followed by faint pair of subparallel, inverted V-shaped carinae on which few scale spikes follow its line. Pleotelson dorsally with 0–6 shallow pits between carinae and lateral crest. Lateral crests and posterior margin of pleotelson margined with sets of about 2–5 directed upward tubercles. Posterior edge of pleotelson with a fringe of long sheathed setae and many short setae.

Antenna 1 with 4 flagellar articles; second article with 4–5 aesthetascs (Fig. 2C). Flagellum of second antenna with 3 articles (Fig. 2D).

Mandibular palp lacking, replaced by single long stout seta (Fig. 2G). Mandibular incisors lack rasp and file. Lacinia mobilis of right mandible branched at intermediate point, the branches gradually curving 90-degrees and serrated on anterior side. Posterior branch slightly longer than or almost same length as anterior branch.

Epipod of *maxilliped*, clavate, approximately 2 times as long as wide, reaching articulation of palp, with simple true setae (Fig. 2B).

Secondary unguis on *pereopod* 1 bifid or trifid (Fig. 3A, B), of pereopods 2–6 bifid (Fig. 3C–G). Pereopod 7 bifid or trifid (Fig. 3H). Ventral comb seta absent on merus and present on carpus of pereopods 6 and 7.

Pleopod 2 with plumose setae up to 0.8 times length of exopod (Fig. 4B). Appendix masculina long, reaching beyond endopod tip, articulating near midlength of endopod. Endopod of pleopod 5, oval (Fig. 4E). Peduncle of pleopod 5 with simple seta laterally. Peduncles with coupling hook sequence 32220.

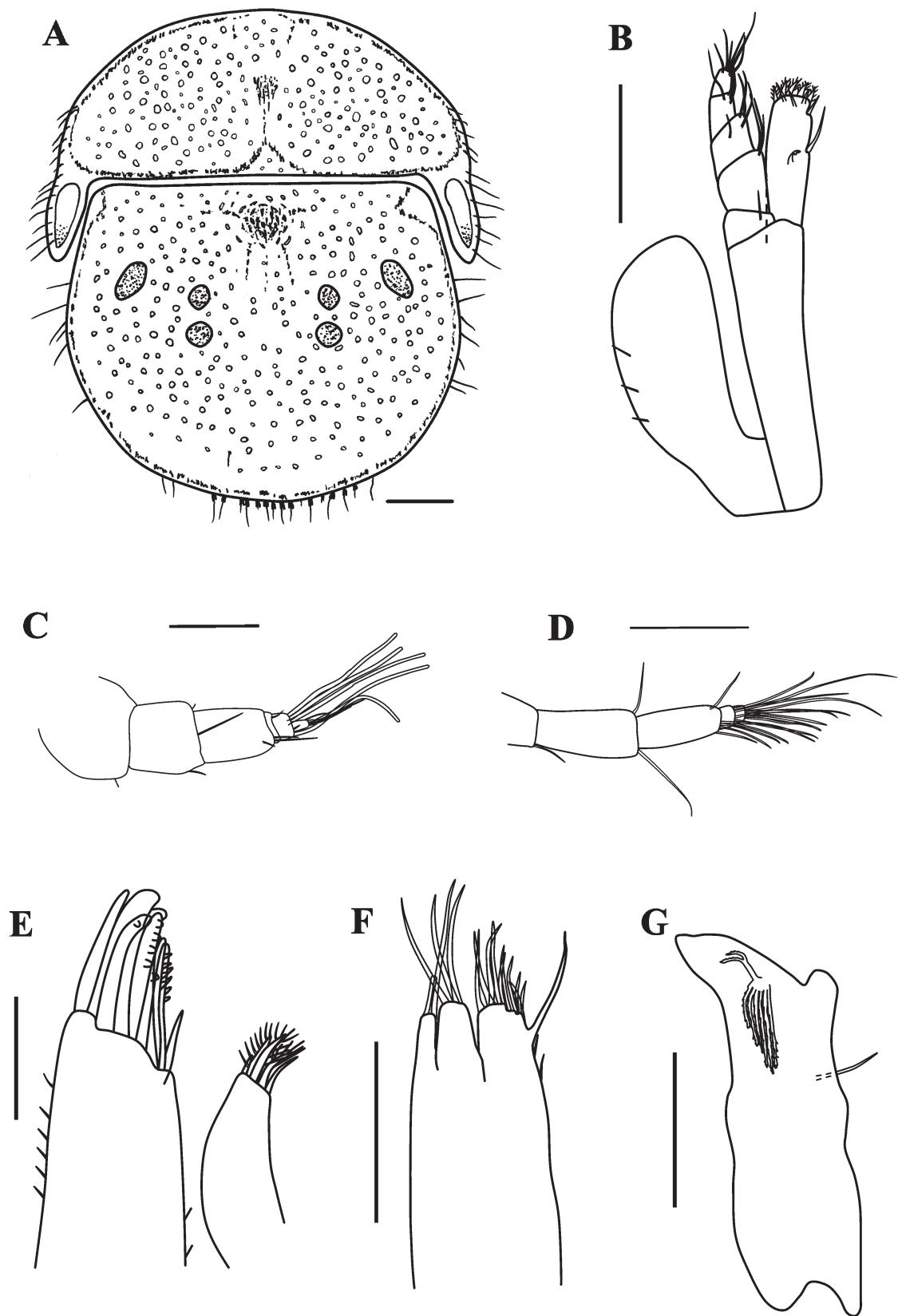


FIGURE 2. *Limnoria furca* sp. nov. Holotype male KMNH IvR 500856. A, pleonite 5 and pleotelson. B, maxilliped. C, antenna 1. D, antenna 2. E, maxilla 1. F, maxilla 2. G, right mandible. Scale bars: A–D, F = 0.1 mm, E = 0.05 mm.

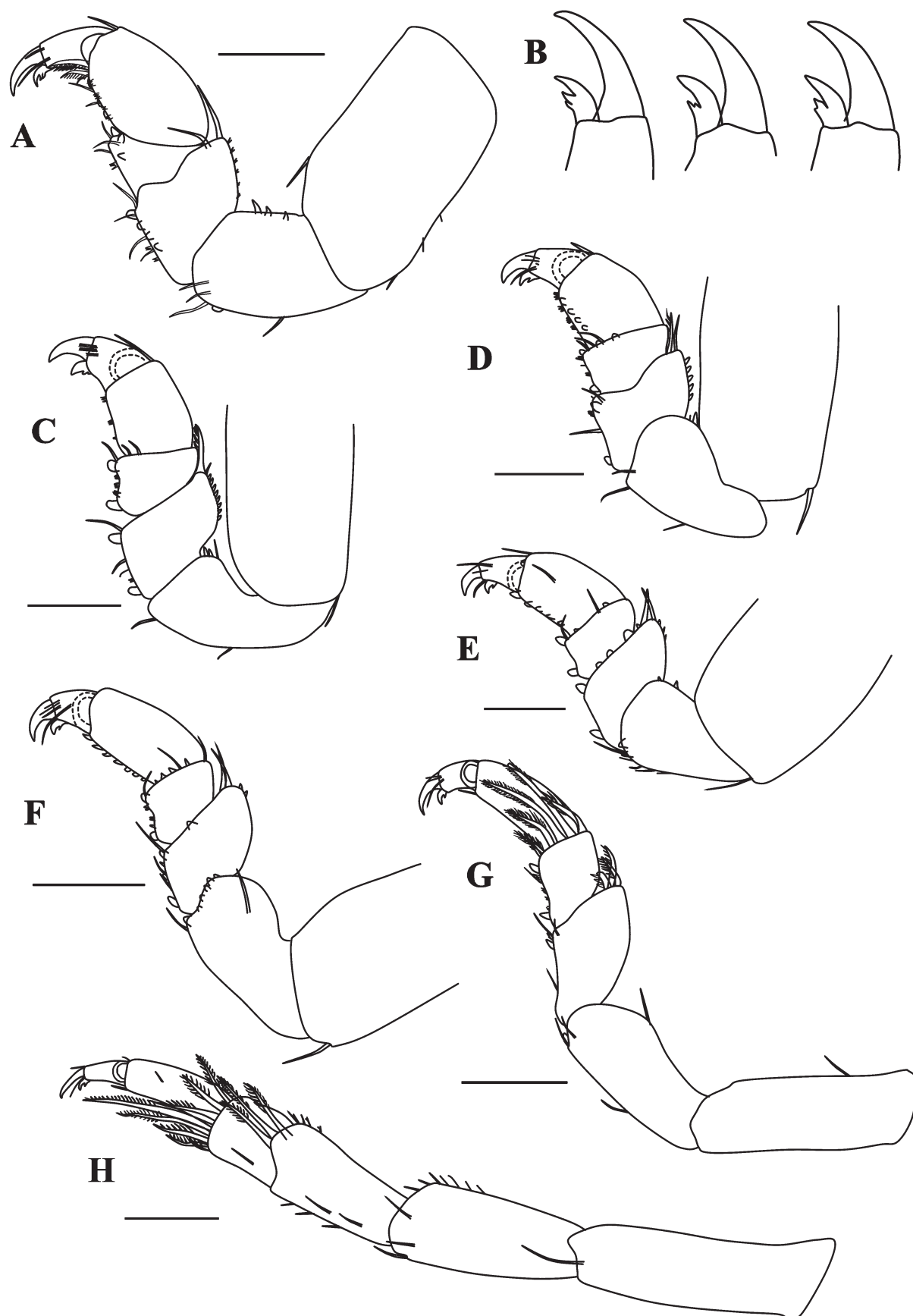


FIGURE 3. *Limnoria furca* sp. nov. Holotype male KMNH IvR 500856. A, pereopod 1. B, dactylus of pereopod 1. C, pereopod 2. D, pereopod 3. E, pereopod 4. F, pereopod 5. G, pereopod 6. H, pereopod 7. Scale bars: A–H = 0.1 mm.

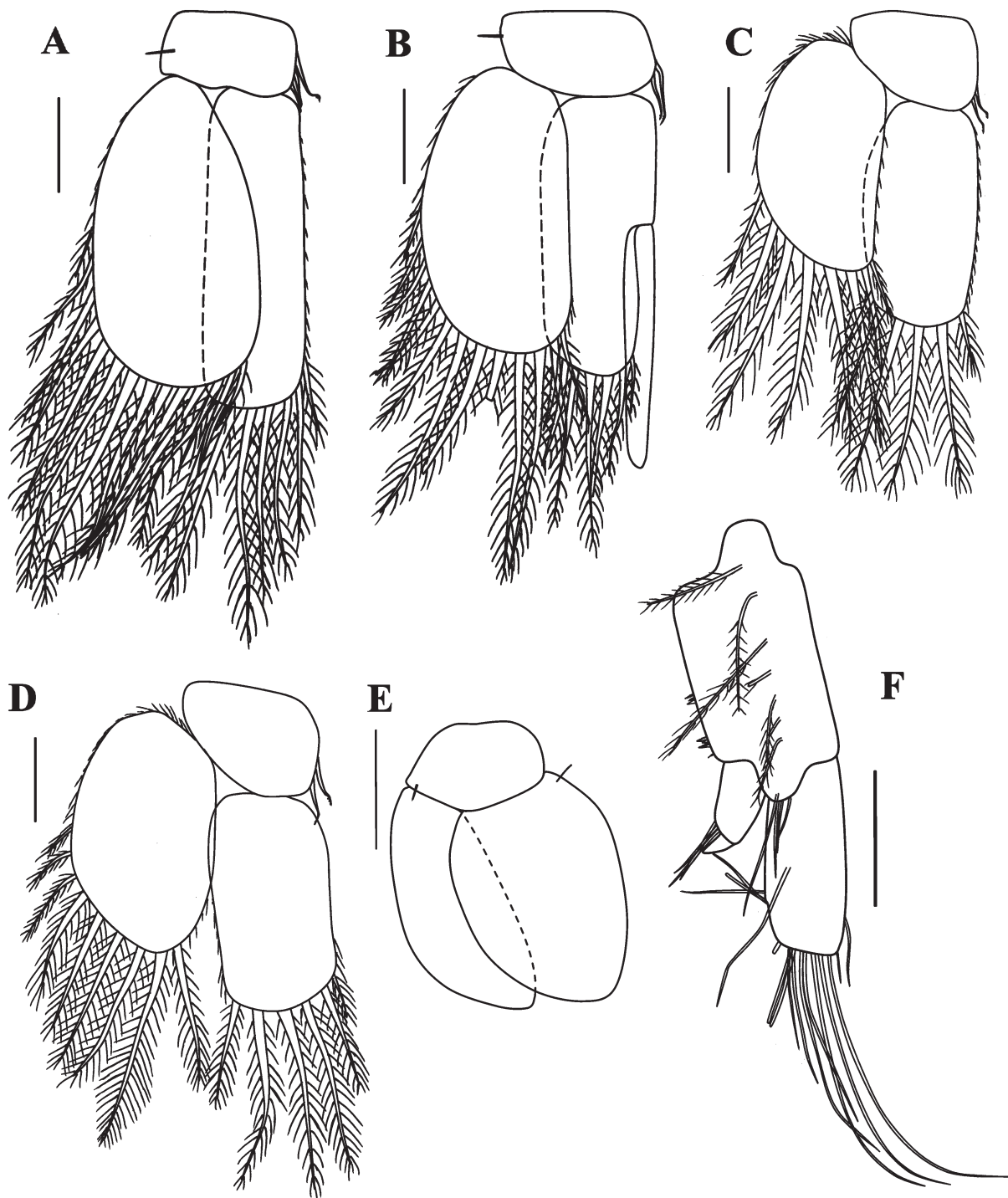


FIGURE 4. *Limnoria furca* sp. nov. Paratype male KMNH IvR 500857. A, pleopod 1. Holotype male KMNH IvR 500856. B, pleopod 2. C, pleopod 3. D, pleopod 4. E, pleopod 5. F, uropod. Scale bars: A–G = 0.1 mm.

Uropod exopod with laterally recurved apical claw (Fig. 4F). Row of simple long setae on endopod placed apically and laterally. Uropod peduncle about 1.6 times as long as endopod. Exopod about 0.3 times as long as peduncle.

Molecular data. COI sequences obtained from the holotype and paratype were deposited in GenBank (accession number: LC146617–LC146632).

Substrate. *Eienia bicyclis* holdfasts.

Distribution. Oki Island, Sea of Japan coast of Honshu Island and Kyushu Island

Etymology. From the Latin for fork, *furca*, referring to the secondary unguis on pereopod 1.

Remarks. Although most *Limnoria*, for example, *L. japonica* and *L. saseboensis*, have a mandibular palp, the mandibular palp of *L. furca* **sp. nov.** is reduced to a seta, a condition also found in 6 other species: *L. bacescui*, *L. bituberculata*, *L. nagatai*, *L. segnoides*, *L. uncapedis* and *L. zinovae* (Cookson 1991, Pillai 1957, Kussakin 1963, Menzies 1957, Nunomura 2012, Ortiz & Lalana 1988). *L. bacescui*, *L. bituberculata*, *L. segnoides*, and *L. uncapedis* differ from *L. furca* **sp. nov.** by the shape of the secondary unguis on the pereopods, and the sculpturing of pleonite 5 and pleotelson. *L. nagatai* has a bifid secondary unguis on all pereopods and clearly marked carinae on pleonite 5 and the pleotelson, while *L. furca* **sp. nov.** has bifid or trifid secondary unguis on pereopods 1 and 7 and weak or absent carinae on pleonite 5 and the pleotelson. *L. zinovae* can be separated from *L. furca* **sp. nov.** by carinae on the pleotelson, the shape of the uropod, lacinia mobilis of right mandible, and the secondary unguis on pereopod 1.

All of our samples of *L. furca* **sp. nov.** were collected from the Sea of Japan side of Honshu and Kyushu Islands, while *L. nagatai* has been collected from the Pacific Ocean side of Honshu and Kyushu Islands. The genetic study of *L. nagatai* and of specimens now identified as *L. furca* **sp. nov.** showed that mitochondrial COI sequence of *L. furca* **sp. nov.** differed from *L. nagatai* by approximately more than 15% in *p*-distance (Yoshino *et al.* 2018).

Limnoria segnoides Menzies, 1957

Figs 5–6

Limnoria segnoides Menzies, 1957: 184–186 fig. 38

Material examined. *Holotype*: non-ovigerous female 2.7 mm (with 3 slides), Misaki, Japan, low tide level, Dr. Th. Mortensen, 16 May 1914 (ZMUC CRU-8050).

Type locality. Misaki, Kanagawa prefecture, Japan.

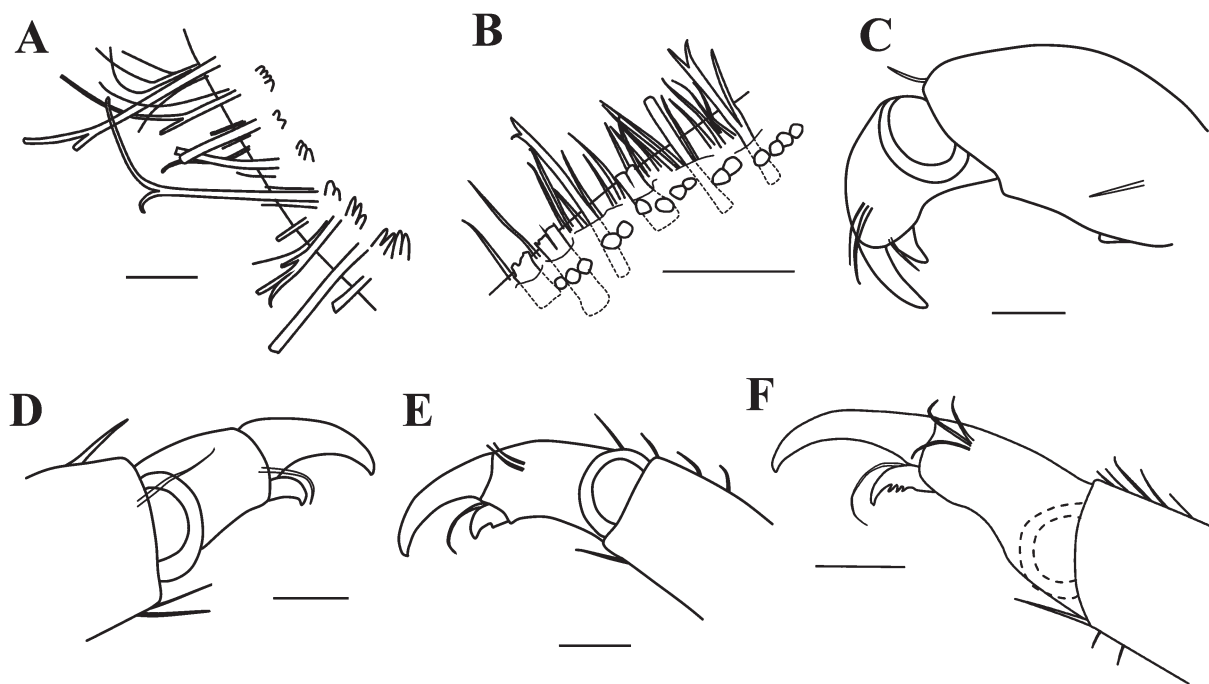


FIGURE 5. *Limnoria segnoides* Holotype female, ZMUC CRU-8050. A, lateral margin of pleotelson. B, posterior margin of pleotelson. C, pereopod 4. D, pereopod 5. E, pereopod 6. F, pereopod 7. Scale bar: A, B = 0.1 mm, C–F = 0.05 mm.

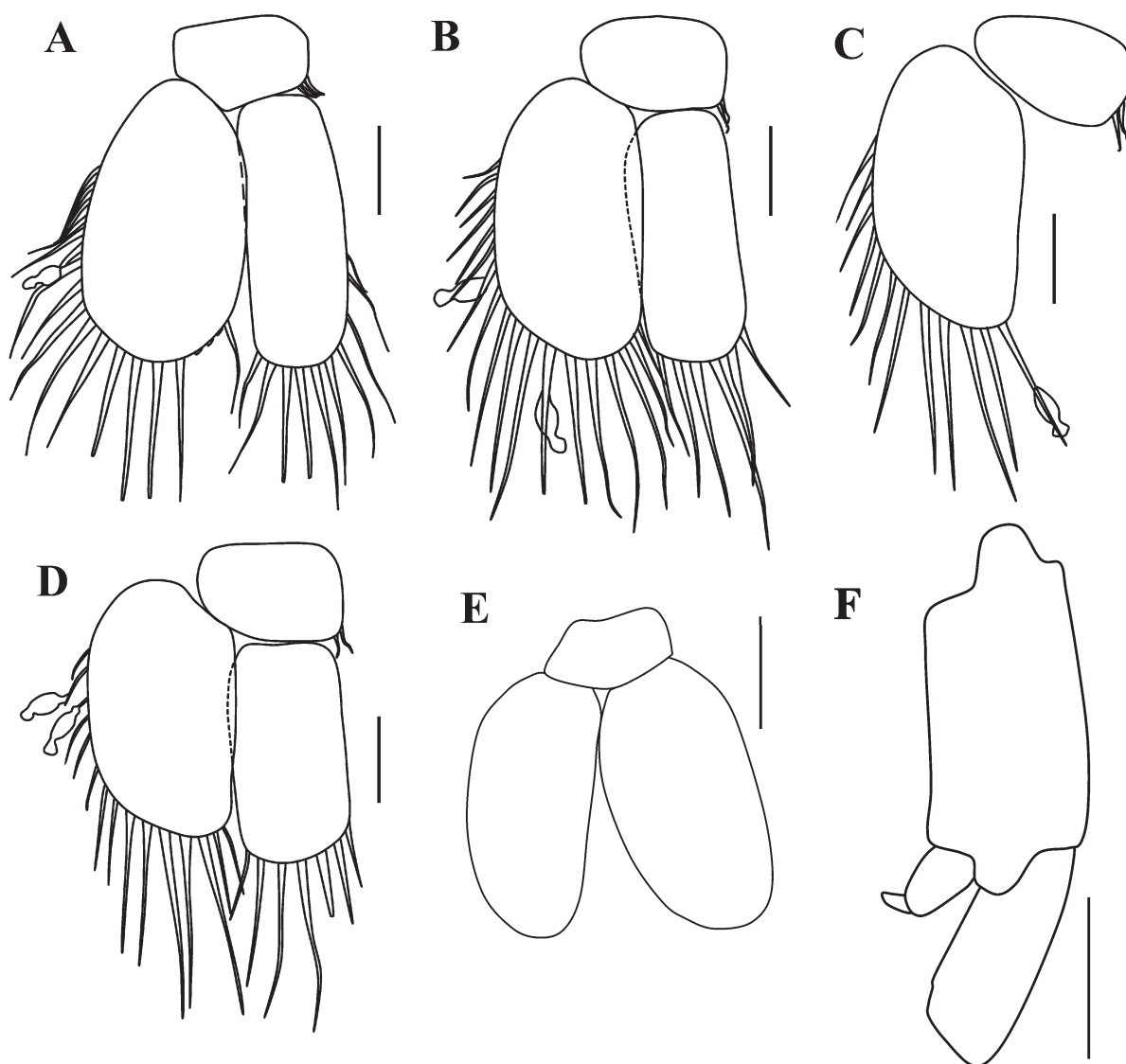


FIGURE 6. *Limnoria segnoides* Holotype female, ZMUC CRU-8050. A, pleopod 1. B, pleopod 2. C, pleopod 3. D, pleopod 4. E, pleopod 5. F, uropod. Scale bar: A–F = 0.1 mm. Setae omitted. Outline of folliculinid protozoans attached to some setae also shown.

Description. *Body* oblong and pale yellow in 70% ethanol. Most of dorsal surface of pereonite, pleon and pleotelson covered with small pores. *Pleon* with 5 distinct segments. *Pereonal* segments 1–4 nearly the same length, segments 4–7 thereafter becoming shorter. Posterior pereonal segments becomes shorter than anterior ones among segments 4–7. Coxal plates of pereonal segments 2–4 rectangular in shape and those of posterior segments prolonged acutely at posterior angle.

Pleonites 1–4 each with transverse row of many small setae. V-shaped carinae dorsomedially on pleonite 5. Pleonite 5 fringed with scale spikes and weak tubercle posteromedially.

Pleotelson medially with 1 large median tubercle followed by 1 pair of subparallel strongly defined carinae on which scale spikes form line. Lateral crests and posterior margin of pleotelson margined with sets of about 3–4 directed upward tubercles (Fig. 5A), which is described as a fringe of dorsally directed spike-like setae in Menzies (1957). Posterior edge of pleotelson with a fringe of thick setae and short thin setae (Fig. 5B).

Secondary unguis on *pereopods* 4 and 5 undivided (Fig. 5C, D). Secondary unguis on pereopod 6 slightly bifid (Fig. 5E). Secondary unguis on left pereopod 7 undivided, with 2 ventral spinules and right pereopod 7 undivided, with 3 ventral spinules (Fig. 5F).

Pleopod 2 with plumose setae up to 0.8 times length of exopod (Fig. 6B). Endopod of pleopod 5, oval, anterior to exopod, 0.9 times as long as endopod of pleopod 2 (Fig. 7E).

Uropod peduncle without lateral tubercles, 1.3 times as long as endopod; exopod without tubercles 0.3 times as long as peduncle (Fig. 6F).

Substrate. Collected from the red alga *Corallina* by washing.

Distribution. Known only from the type locality.

Remarks. Menzies (1957) did not provide sufficient description of this species for modern comparisons. Only one specimen of *Limnoria segnoides* is in the collection as holotype at CZM. Unfortunately, some parts were missing: antenna, mouth parts, head, pereopod 1–3, thick setae on posterior margin of pleotelson. Fortunately, the shape of maxilliped, dactylus of first pereopod, outer surface of left mandible and lacinia mobilis and setal row of right mandible were written in Menzies (1957), “Epipod of maxilliped clavate, widest at mid-region, about three times as long as wide and extending to articulation of palp with endopod. Mandibular palp lacking but is replaced by a stout long seta. [...] Laciniod seta of right mandible composed of two simple marginally serrated setae which are similar to those in setal row.” Menzies’s sketch suggested that anterior lobe of the lacinia mobilis of right mandible was slightly shorter than posterior lobe, secondary unguis on pereopod 1 is undivided, and mandibular incisors lack rasp and file.

We were able to provide additional information such as on the dactylus of pereopods 4–7, lateral and posterior margin of pleotelson, and pleopod 5, based on holotype specimen. We were not able to determine whether there are sheathed setae on posterior margin of pleotelson because all thick setae were broken and Menzies (1957) did not draw them.

There are 7 species where the mandibular palp is replaced by a single stout seta: *L. furca* **sp. nov.**, *L. bacescui*, *L. bituberculata*, *L. nagatai*, *L. segnoides*, *L. uncapedis* and *L. zinovae* (Cookson 1991, Pillai 1957, Kussakin 1963, Menzies 1957, Nunomura 2012, Ortiz & Lalana 1988). *L. bacescui* and *L. zinovae* differ from *L. segnoides* by shape of uropod, sculpturing of pleonite 5 and pleotelson and no branched lacinia mobilis of right mandible (*L. segnoides* has 2 branched lacinia mobilis). *L. bituberculata*, *L. segnoides* and *L. uncapedis* share similar shape of lacinia mobilis of right mandible, but *L. segnoides* is separated from other 2 species by lacking the accessory spinules on the secondary unguis on pereopod 1 and by the distinctive sculpturing on pleonite 5 and the pleotelson. *L. segnoides* has undivided secondary unguis on pereopod 1 and V-shaped carina on pleonite 5, while *L. furca* **sp. nov.** has bifid or trifid secondary unguis on pereopod 1 and Y-shaped carina on pleonite 5 and *L. nagatai* has bifid secondary unguis on pereopod 1 and Y-shaped carina on pleonite 5.

Limnoria nagatai Nunomura, 2012

Figs 9–10

Limnoria nagatai Nunomura, 2012: 80–82 fig. 2

Material examined. Holotype: male, 4.2 mm, Sumiyoshizaki, Kunimi-cho (now Kunisaki-shi), Oita Prefecture, Japan, Nagata Kizo, 13 June 1978 (TOYACr-23340)

Allotype: ovigerous female, 4.7 mm, Ryozaiki, Kunimi-cho (now Kunisaki-shi), Oita Prefecture, Japan, Nagata Kizo, 1976 or 1977 (TOYA Cr-23345).

Paratypes: 4 males, 3.0–5.1 mm, Ryozaiki, Kunimi-cho (now Kunisaki-shi), Oita Prefecture, Japan, Nagata Kizo, 19 May 1977 (TOYA Cr-23341–23344; Cr-23341 lost, Cr-23342 lost, Cr-23343 head lost, Cr-23344 lost).

Other material: female 2.6 mm (with 26 slides), Kamogawa-shi, Chiba prefecture, Japan, 35°07'N, 140°10'E, subtidal zone, *Eisenia bicyclis* holdfasts, Takeshi A. Ohsawa and Hiroki Yoshino, 23 April 2012 (KMNH IvR 500790); 3 males, 2.2–2.7 mm, 4 ovigerous females, 2.6–3.3 mm, 6 non-ovigerous females, 1.9–3.4 mm (KMNH IvR 500791), same as KMNH IvR 500790; 1 male, 2.7 mm, 4 non-ovigerous females, 1.9–3.5 mm, Tokura, Minamisanriku-cho, Miyagi prefecture, Japan, 38°38'N, 141°26'E, subtidal zone, *Eisenia bicyclis* holdfasts, Takeshi A. Ohsawa and Hiroki Yoshino, 9 April 2013 (KMNH IvR 500792); 1 female, 2.5 mm, Oppa-wan, Kitakami-machi, Ishinomaki-shi, Miyagi prefecture, Japan, 38°36'N, 141°30'E, subtidal zone, *Eisenia bicyclis* holdfasts, Takeshi A. Ohsawa and Hiroki Yoshino, 9 April 2013 (KMNH IvR 500793); 1 male, 2.4 mm, 1 ovigerous female, 2.9 mm, 2 non-ovigerous females 1.9 (head lost)–2.0 mm, Hiraio-cho, Hitachinaka-shi, Ibaraki prefecture, Japan, 36°21'N, 140°36'E, subtidal zone, *Eisenia bicyclis* holdfasts, Hiroki Yoshino, 8 April 2013

(KMNH IvR 500794); 1 male, 1.8 mm, 1 non-ovigerous female, 2.8 mm, Mizuki-cho, Hitachi-shi, Ibaraki prefecture, Japan, 36°31'N, 140°38'E, subtidal zone, *Eisenia bicyclis* holdfasts, Takeshi A. Ohsawa and Hiroki Yoshino, 2 June 2013 (KMNH IvR 500795); 1 male 1.8 mm, 1 ovigerous female, 3.3 mm, 2 non-ovigerous females, 1.8–3.2 mm, Choshi-shi, Chiba prefecture, Japan, 35°41'N, 140°51'E, subtidal zone, *Eisenia bicyclis* holdfasts, Takeshi A. Ohsawa and Hiroki Yoshino, 3 June 2012 (KMNH IvR 500796); 4 males 1.7–2.5 mm, 2 non-ovigerous females, 1.9–2.3 mm, Okinoshima Island park, Tateyama-shi, Chiba prefecture, Japan, 34°59'N, 139°49'E, subtidal zone, *Eisenia bicyclis* holdfasts, Takeshi A. Ohsawa and Hiroki Yoshino, 9 June 2013 (KMNH IvR 500797); 1 male, 1.8 mm, 1 non-ovigerous female, 2.2 mm, Hagi, Futtsu-shi, Chiba prefecture, Japan, 35°11'N, 139°49'E, subtidal zone, *Eisenia bicyclis* holdfasts, Hiroki Yoshino, 23 December 2013 (KMNH IvR 500798); 1 ovigerous female, 2.5 mm, 1 non-ovigerous female, 2.2 mm, Kisami Ohama Beach, Shimoda-shi, Shizuoka prefecture, Japan, 34°39'N, 138°55'E, Takeshi A. Ohsawa and Hiroki Yoshino, 13 April 2013 (KMNH IvR 500799); 3 males, 2.7 mm, 4 females, 3.0–4.0 mm, Hamajima-cho, Shima-shi, Mie Prefecture, Japan, 34°18'N, 136°44'E, subtidal zone, *Eisenia arborea* holdfasts, Takeshi A. Ohsawa and Hiroki Yoshino, 3 July 2012 (KMNH IvR 500856); 4 males, 1.8–3.0 mm, 5 females, 2.5–3.4 mm, Hiwasaura, Minami-cho, Kaifu-gun, Tokushima Prefecture, Japan, subtidal zone, *Eisenia bicyclis* holdfasts, Takeshi A. Ohsawa and Hiroki Yoshino, 28 April 2013 (KMNH IvR 500857); 1 male, 2.8 mm, 1 female, 3.0 mm, Abe port, Minami-cho, Kaifu-gun, Tokushima Prefecture, Japan, subtidal zone, *Eisenia bicyclis* holdfasts, Takeshi A. Ohsawa and Hiroki Yoshino, 28 April 2013 (KMNH IvR 500858).

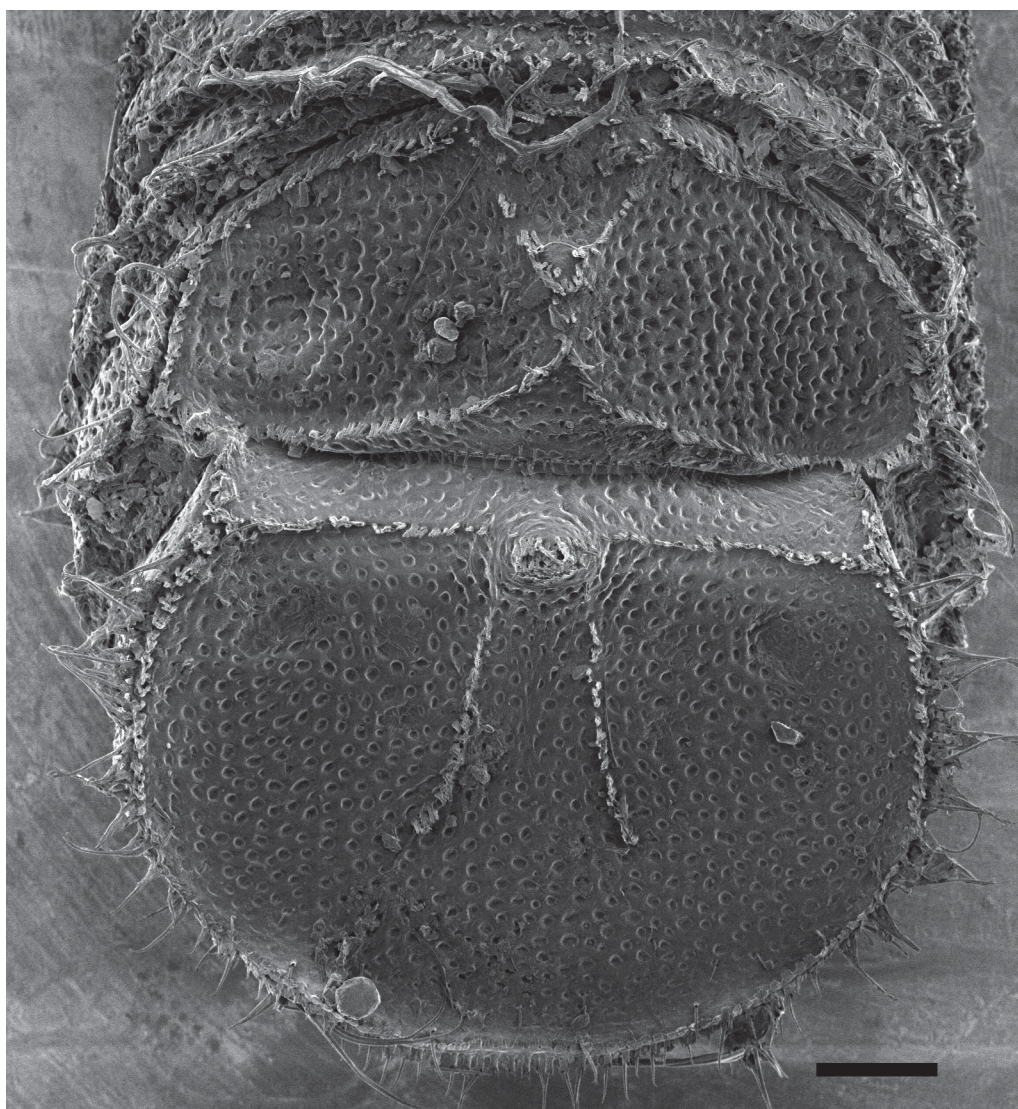


FIGURE 7. *Limnoria nagatai* Female KMNH IvR 500790. Dorsal view of pleonite 5, pleotelson. Scale bars: 0.1 mm.

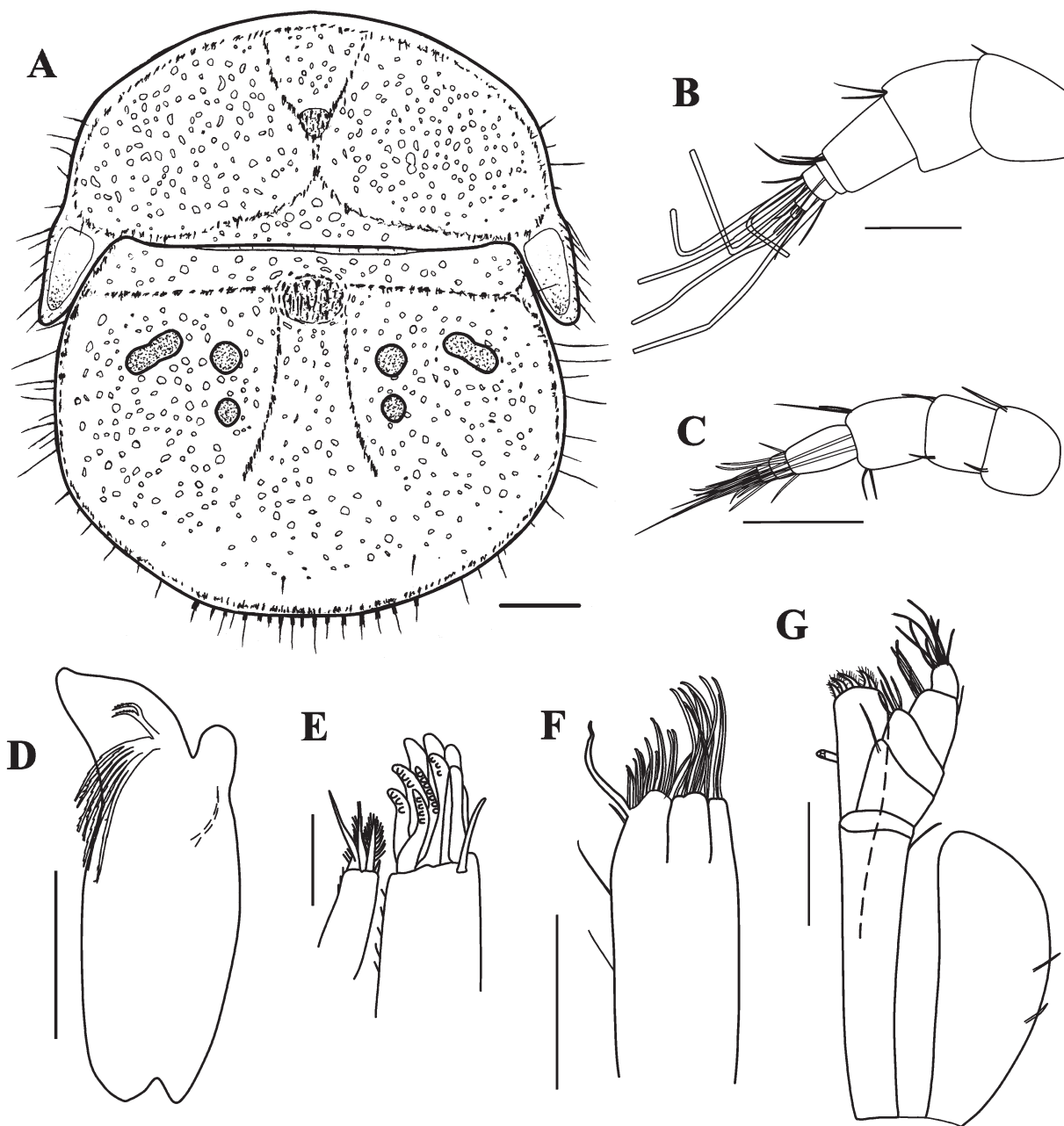


FIGURE 8. *Limnoria nagatai* Female KMNH IvR 500790 A, pleotelson. Holotype male TOYACr-23340. B, antenna 1. C, antenna 2. D, right mandible. female KMNH IvR 500796. E, maxilla 1. Holotype male TOYACr-23340. F, maxilla 2. G, maxilliped. Scale bars: A–C= 0.1 mm, D–G = 0.05 mm,

Type locality. Sumiyoshizaki, Kunimi-cho (now Kunisaki-shi), Oita Prefecture, Japan

Description. *Body* oblong and pale yellow to pale red in 70% ethanol. *Head* almost globular, some samples red in color, about 1.4 times broader than long. *Eyes* black in color, each with 7 ommatidia. Most of dorsal surface of pereonite, pleon and pleotelson covered with small pores. *Pleonites* with 5 distinct segments. *Pereonal* segment 1 longest, about 1.5 times longer than segment 2. Segments 2–4 subequal length. Posterior pereonal segments 4–7 progressively shorten. Coxal plates of pereonal segments 2–4 rectangular in shape and those of posterior segments prolonged acutely at posterior angle. Pereonites 6, 7 and Pleonites 1 to 4 each with transverse row of many small setae.

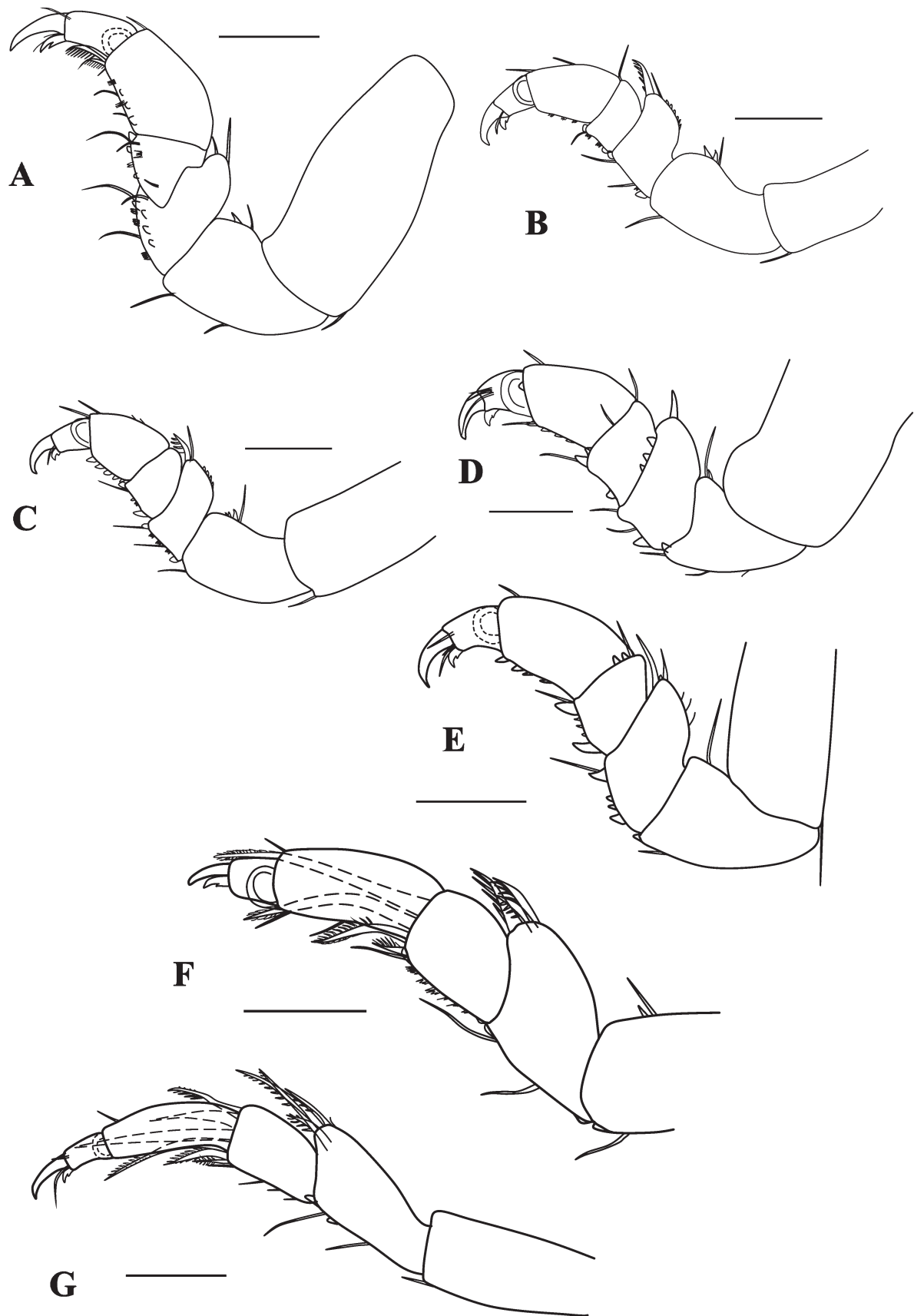


FIGURE 9. *Limnoria nagatai* Holotype male TOYACr-23340. A, pereopod 1. B, pereopod 2. C, pereopod 3. D, pereopod 4. E, pereopod 5. F, pereopod 6. G, pereopod 7. Scale bars: A–G = 0.1 mm.

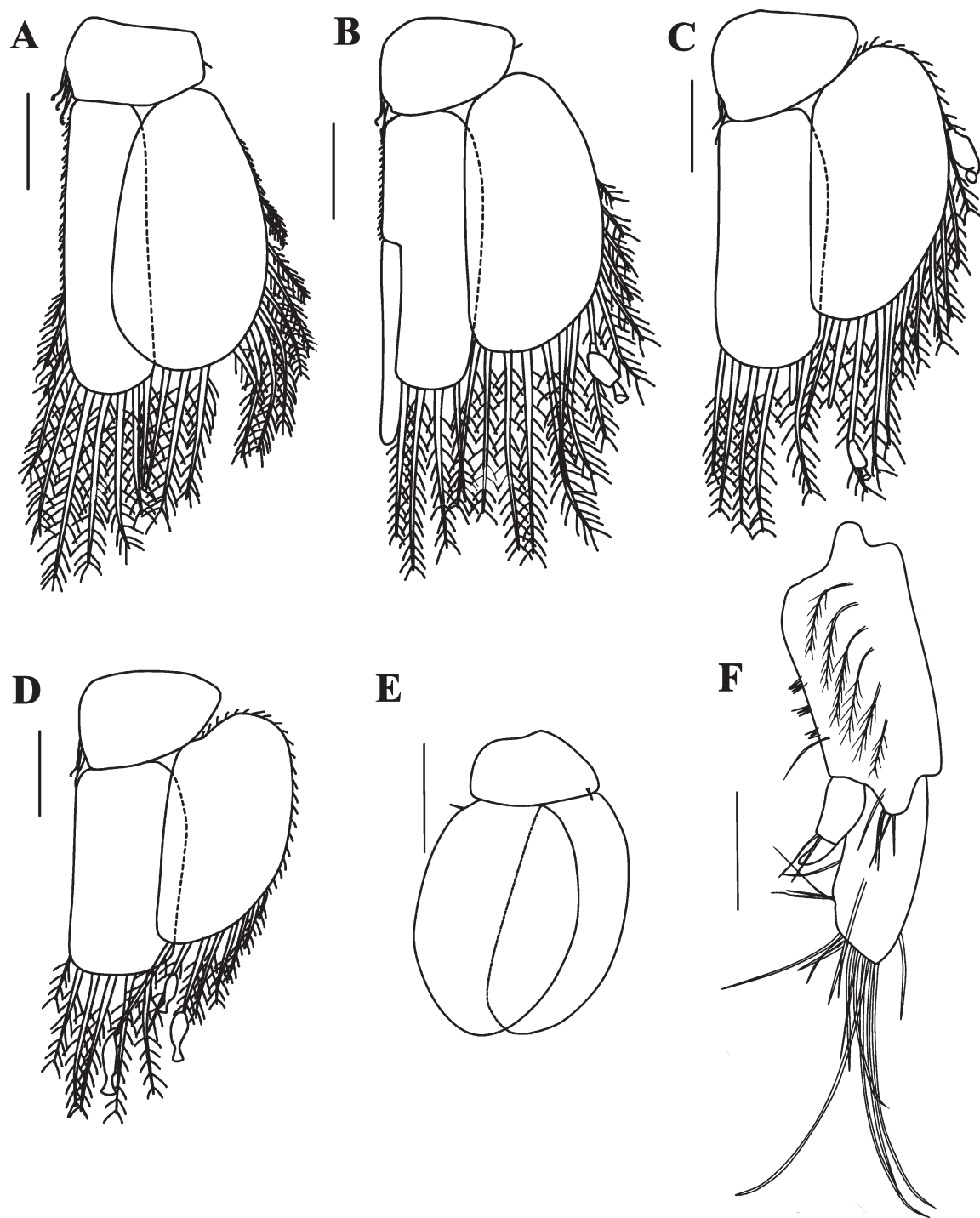


FIGURE 10. *Limnoria nagatai* Paratype male TOYA Cr-23343. A, pleopod 1. B, pleopod 2. C, pleopod 3. D, pleopod 4. E, pleopod 5. F, uropod. Scale bars: A–F = 0.1 mm. Outline of folliculinid protozoans attached to some setae also shown.

Pleonite 5 0.65 times as long as pleotelson (Fig. 8A). *Pleonite 5* dorsomedially with Y-shaped or nearly X-shaped carinae on which scale spikes form line (Fig. 7). These spikes continuing laterally and *pleonite 5* fringed with spikes. Posterior margin of *pleonite 5* with sparsely populated scale-spikes. *Pleonite 5* medially with 1 strong tubercle and 1 weaker tubercle posteriorly.

Pleotelson approximately 0.55–0.8 times as long as wide, medially with 1 strong tubercle followed by 1 pair of subparallel carinae on which scale spikes form line that appears as an inverse V-shaped structure on the pleotelson

(Fig. 8A). Pleotelson dorsally with 0–6 shallow pits between carinae and lateral crest. Lateral crests and posterior margin of pleotelson margined with sets of about 3–4 directed upward tubercles. Posterior edge of pleotelson with a fringe of long stout setae and many short setae.

Antenna 1 with 4 flagellar articles; second article with 5 aesthetascs (Fig. 8B). Flagellum of second antenna with 3 articles (Fig. 8C).

Mandibular palp lacking, replaced by single stout long seta (Fig. 8D). Mandibular incisors lack rasp and file. Lacinia mobilis of right mandible branched at intermediate point, the branches gradually curving 90-degrees or more and serrated on anterior side. Anterior and posterior branches almost same length.

Epipod of *maxilliped*, clavate, approximately 2–3 times as long as wide, slightly reaching articulation of palp (Fig. 8G).

Secondary unguis on all *pereopods* bifid (Fig. 9). Exceptionally, only right pereopod 1 of one individual from Ibaraki prefecture (KMNH IvR 500794), slightly trifid. Ventral comb seta absent on merus and present on carpus of pereopods 6, 7.

Pleopod 2 with plumose setae up to 0.8 times length of exopod (Fig. 10B). Appendix masculina long, reaching beyond endopod tip, articulating near midlength of endopod. Endopod of pleopod 5, oval, 0.8 times as long as endopod of pleopod 2 (Fig. 10E). Peduncle of pleopod 5 with simple seta laterally. Peduncles with coupling hook sequence 32220.

Uropod peduncle 1.6 times as long as endopod. Exopod 0.3 times as long as peduncle (Fig. 10F).

Molecular data. COI sequences obtained from our materials were deposited in GenBank (accession number: LC146527–LC146632).

Substrates. *Eisenia bicyclis* and *E. arborea*. Unknown in type locality.

Distribution. Pacific coast of Honshu Island, Shikoku Island and Kyushu Island.

Remarks. This work has provided some morphological and substrate details omitted in the original description of *Limnoria nagatai* (Nunomura, 2012). Nunomura (2012) did not describe the substrate, and that the mandibular palp was reduced to a seta although they described, “Palp not found.” Most of needed notes are added in the above description.

The mandibular palp of *L. nagatai* is reduced to a seta. *L. nagatai* is most similar to *L. furca* **sp. nov.** and *L. segnoides* in that they share a bifid lacinia mobilis of the right mandible, inverse V-shaped carinae on pleotelson, and similarly shaped uropods. *L. nagatai* is separated from *L. furca* **sp. nov.** and *L. segnoides* by bifid secondary unguis on all pereopods, Y-shaped carinae on pleonite 5 and clear and strong carinae on pleonite 5 and pleotelson.

L. nagatai feeds on the holdfasts of *Eisenia* in Honshu Island and east side of Shikoku Island. *L. nagatai* tended to live in bigger holdfasts of *E. bicyclis*. They may bore into the substrates, making long pits and, finally, causing the holdfasts to look like a sponge. More than 100 individuals have been found from a single holdfast.

Discussion

Limnoria furca **sp. nov.** and *L. nagatai* make their burrows in the brown alga genus *Eisenia*, which is used as food, but were collected from allopatric locations, the coasts of the Sea of Japan and the Pacific Ocean in Japan, respectively. Although we surveyed around Boso Peninsula near the type locality of *L. segnoides*, we could not find it but just many samples of *L. nagatai*. *L. segnoides* was collected on May 26, 1914, and it has never since been recorded. Further collection is required in order to describe male morphology because *L. segnoides* was described based only upon one female specimen.

There are seven *Limnoria* species that show reduced mandibular palps to a seta: *L. furca* **sp. nov.**, *L. bacescui*, *L. bituberculata*, *L. nagatai*, *L. segnoides*, *L. uncapedis* and *L. zinovae*. Moreover, these species are algal-feeding and have clavate shaped epipods of maxilliped, except *L. zinovae*, which is seagrass-feeding and its shape of epipod of maxilliped is unknown. Hence, this group of non-mandibular-palp species might be considered as monophyletic. Also, *L. furca* **sp. nov.**, *L. nagatai*, *L. segnoides* and *L. zinovae* have similar inverse V-shaped carinae on the pleotelson, similar shape of pereopods and uropod, and all are found in Japan, which implies that these four species are closely related.

Acknowledgements

We are particularly grateful to Yuriko Kambara who helped us collect the specimens. Dr. Jørgen Olesen of the ZMUC kindly granted access to the material of *L. segnoides*. Dr. Hisashi Negoro of the TOYA also kindly loaned the materials of *L. nagatai*. We thank Dr. Harufumi Nishida (Chuo University) and Dr. Julien Legrand (Chuo University) for the rental of microscope and technical support. We also thank Dr. Michitaka Shimomura (KMNH) for assisting with specimen dissection and the deposition of type series.

References

- Cookson, L.J. (1991) Australasian species of Limnoriidae (Crustacea: Isopoda). *Memoirs of Museum Victoria*, 52, 137–262.
<https://doi.org/10.24199/j.mmv.1991.52.02>
- Kussakin, O.G. (1963) Some data on the systematics of the family Limnoriidae (Isopoda) from northern and far-eastern seas of the USSR. *Crustaceana*, 5 (4), 281–292.
<https://doi.org/10.1163/156854063X00237>
- Menzies, R.J. (1957) The marine borer family Limnoriidae (Crustacea, Isopoda). Part I: Northern and Central America: Systematics, distribution, and ecology. *Bulletin of Marine Science*, 7 (2), 101–200.
- Nunomura, N. (2008) Marine Isopod crustaceans collected from Shijiki Bay, western Japan (1). Valvifera, Cymothoida, Sphaeromatidea, Limnoriidea and Oniscidea. *Bulletin of the Toyama Science Museum*, 31, 13–43.
- Nunomura, N. (2012) Marine isopod crustaceans of Seto Inland Sea deposited at Toyama Science Museum, 3. Suborder Cymothoida, Limnoriidea and Sphaeromatidea. *Contributions from the Toyama Science Museum*, 35, 77–85.
- Ortiz, M. & Lalana, R. (1988) Una nueva especie del genero Phycolimnoria (Isopoda, Limnoriidae) de aguas cubanas. *Revista de Investigaciones Marinas*, 9 (2), 37–42. [in Spanish]
- Pillai, N.K. (1957) A new species of *Limnoria* from Kerala. *Bulletin of the Central Research Institute, University of Kerala*, 5 (2), 149–157.
- Richardson, H. (1909) Isopods collected in the northwest Pacific by the US Bureau of Fisheries Steamer "Albatross" in 1906. *Proceedings of the United States National Museum*, 37, 75–129.
<https://doi.org/10.5479/si.00963801.37-1701.75>
- Shiino, S.M. (1950) The marine wood-boring crustaceans of Japan. I. Limnoriidae. *The Wasmann Journal of Biology*, 8, 333–358.
- Song, J., Park, T., Kim, W. & Min, G. (2017) *Arcturina serrulatus* sp. nov. and a new record of *Limnoria rhombipunctata* (Crustacea: Malacostraca: Isopoda) from South Korea. *Zootaxa*, 4286 (3), 411–424.
<https://doi.org/10.11646/zootaxa.4286.3.8>
- Yoshino, H., Watabe, H. & Ohsawa, T.A. (2017) A new species of seagrass-boring *Limnoria* (Limnoriidae, Isopoda, Crustacea) from Japan. *Zootaxa*, 4232 (2), 251–259.
<https://doi.org/10.11646/zootaxa.4232.2.8>
- Yoshino, H., Yamaji, F. & Ohsawa, T.A. (2018) Genetic structure and dispersal patterns in *Limnoria nagatai* (Limnoriidae, Isopoda) dwelling in non-buoyant kelps, *Eisenia bicyclis* and *E. arborea*, in Japan. *PLoS ONE*, 13 (6), e0198451.
<https://doi.org/10.1371/journal.pone.0198451>